

WHAT IS CLAIMED IS:

1 1. A method for estimating digital data received over a potentially noisy
2 channel which adds intersymbol interference or additive noise, or a combination of
3 intersymbol interference or additive noise, the method comprising steps of: *E A Panel,*

4 inputting data received from the noisy channel into a SISO MMSE equalizer;
5 inputting a set of priors over symbol values of the noisy channel including a
6 separate prior for each received noisy channel symbol value, into the SISO MMSE equalizer;
7 equalizing, by an MMSE equalization in the SISO MMSE equalizer, the data
8 received from the noisy channel and the set of priors over symbol values to produce a symbol
9 value estimate;

10 mapping output of the SISO MMSE equalizer onto priors over the symbol
11 values to produce a confidence indication in each of the symbol value estimates as a function
12 of time.

1 2. The method according to claim 1, further comprising a step of setting
2 parameters of the SISO MMSE equalizer according to MMSE ~~criterion over statistics of the~~
3 channel noise and ~~statistics of the symbol values.~~

1 4 3. The method according to claim 1, wherein digital data transmitted over
2 said potentially noisy channel is error correction encoded prior to transmission, the step of
3 mapping output of the SISO MMSE equalizer comprising steps of:

4 passing output of the SISO MMSE equalizer into a SISO error correction
5 decoder;

6 using an output of said SISO error correction decoder as the set of priors over
7 symbol values;

8 repeating all steps of the method until a predetermined convergence criterion
9 is reached between said SISO error correction decoder and said SISO MMSE equalizer.

1 4. The method according to claim 3, wherein digital data transmitted over
2 said potentially noisy channel is interleaved prior to transmission and a step of de-
3 interleaving is conducted on the output of the SISO MMSE equalizer prior to said step of
4 passing output of the SISO error correction decoder is interleaved prior to said step of
5 repeating.

1 5. The method according to claim 4, wherein said step of equalizing
2 excludes symbol value estimates which are functions of an input distribution of a current
3 symbol being equalized.

1 6. The method according to claim 5, wherein said SISO error correction
2 decoder has its output restricted to exclude symbol value estimates which are functions of
3 an input distribution of a current symbol being decoded.

1 7. The method according to claim 1, wherein said step of equalizing
2 comprises a fast update equalization of the order M^2 (quadratic in the number of parameters
3 M) which exploits redundant computations in successive equalizer computations.

1 8. The method according to claim 7, wherein the fast update equalization
2 is performed by applying the matrix inversion lemma to a matrix to be inverted in a design
3 of equalization coefficients for the SISO MMSE equalizer.

1 9. The method according to claim 1, wherein said data is multi-
2 dimensional and is error correction encoded then interleaved prior to transmission in the
3 channel, and wherein said SISO MMSE equalizer handles single-input multiple output data,
4 the mapping step comprising steps of:

5 de-interleaving outputs of the SISO MMSE equalizer and re-serializing data
6 output from the SISO MMSE equalizer into one-dimensional encoding;

7 SISO decoding the re-serialized output of the SISO MMSE equalizer; and

8 repeating said equalizing and mapping steps until a predetermined convergence
9 criterion is met between said equalizing and SISO decoding steps.

10 10. A method for equalization and decoding of digital data received over
11 a multiple noisy channels which each add intersymbol interference or additive noise, or a
12 combination of intersymbol interference or additive noise, wherein data transmitted over each
13 channel is interleaved prior to transmission, the method comprising steps of:

14 performing a soft equalization for each channel by

15 inputting data received from said one of the noisy channels into a SISO MMSE
equalizer;

inputting a set of priors over symbol values of the noisy channel including a
separate prior for each received noisy channel symbol value, into the SISO MMSE equalizer;

equalizing, by an MMSE equalization in the SISO MMSE equalizer, the data
received from the noisy channel and the set of priors over symbol values; and

mapping output of the SISO MMSE equalizer onto priors over the symbol
values to produce a confidence indication in each of the symbol values as a function of time,

then, using de-interleaved output from said mapping step for one channel, iteratively
decoding information for a second channel by repeating said performing a soft equalization

16 while substituting said de-interleaved output for said set of priors and substituting output
17 from said mapping step for said second channel for said data received until a predetermined
18 convergence criterion is reached.

1 11. A data decoding device comprising:
2 a SISO MMSE equalizer;
3 a SISO decoder, the decoder exchanging symbol estimates with the SISO
4 MMSE equalizer, the SISO MMSE equalizer produces MMSE linear estimates of transmitted
5 symbols $\hat{b}[n]$, and mapping the linear estimates to an output set of priors over the symbols
6 π_{OUT}^E .

107 12. The device according to claim 11, wherein said equalizer maps the
estimates by treating the output distribution $\hat{b}[n]$ as conditionally Gaussian, and distributed
about the symbol values.

1 13. The device according to claim 12, wherein the output distribution
2 mapping is defined as:

$$Prob\{b[n] = 1 | \hat{b}[n]\} = \frac{1}{2} \left(1 + \tanh \left(\frac{\hat{b}[n]}{\sigma_b^2} \right) \right),$$

4 where σ_b^2 is the variance of the conditional output distribution given the symbol $\hat{b}[n] = \text{sign}(\hat{b}[n])$.
5 and the estimate $\hat{b}[n]$ cannot be a function of $\pi_{IN}^E[n]$, and expectations are taken over a
6 distribution of the symbols which excludes $\pi_{IN}^E[n]$ for the calculation of $\hat{b}[n]$.

14. The device according to claim 12, wherein the following steps for computing the output distribution given the observations, $x[n]$ and the input distribution π_{IN}^E is used by the MMSE equalizer:

a. Create buffers for the priors, the signal $x[n]$, the expectations $\vec{bb}[n] = E\{b[n]\bar{b}[n]\}$, the correlation matrix $B[n] = E\{\bar{b}[n]\bar{b}[n]^T\}$, and the means $\vec{mb}[n] = E\{\bar{b}[n]\}$

$$\vec{\pi}^{(n)} \triangleq [\pi^{(n)}[-N_1 - L_2], \dots, \pi^{(n)}[0], \dots, \pi^{(n)}[N_2 + L_1]]^T$$

$$\vec{x}^{(n)} \triangleq [x^{(n)}[-N_1], \dots, x^{(n)}[0], \dots, x^{(n)}[N_2]]^T$$

$$\vec{bb}^{(n)} \triangleq [bb^{(n)}[-N_1 - L_2], \dots, bb^{(n)}[0], \dots, bb^{(n)}[N_2]]^T = [0, \dots, 0, 1, 0, \dots, 0]^T$$

b. Initialize buffers for priors $\vec{\pi}^{(n)}$ and data $\vec{x}^{(n)}$, in terms of the signal $x[n]$ and the input π_{IN}^E .

$$\vec{x}^{(0)} = [0, 0, \dots, x[0], x[1], \dots, x[N_2]]^T$$

$$\vec{\pi}^{(0)} = [0, 0, \dots, 0, \pi_{IN}^E[0], \pi_{IN}^E[1], \dots, \pi_{IN}^E[N_2 + L_1]]^T$$

c. Loop over the data for $n=0, \dots, N$:

$$\pi^{(n)}[0] = 1/2$$

$$\vec{mb}^{(n)} = 2 \vec{\pi}^{(n)} - 1$$

$$B = \vec{mb}^{(n)} \vec{mb}^{(n)T}$$

$$\text{diag}(B) = \text{diag}(1, 1, \dots, 1)$$

$$\vec{c}[n] = [H (B - \vec{mb}^{(n)} \vec{mb}^{(n)T}) H^T + \sigma_w^2 I]^{-1} H \vec{bb}^{(n)}$$

$$\hat{b}[n] = \vec{mb}^{(n)} + \vec{c}^{(n)T} (\vec{x}^{(n)} - H \vec{mb}^{(n)})$$

$$\vec{x}^{(n+1)} = [x^{(n)}[-N_1 + 1], \dots, x^{(n)}[N_2], 0]$$

$$\vec{\pi}^{(n+1)} = [\pi^{(n)}[-N_1 - L_2 + 1], \dots, \pi^{(n)}[N_2 + L_1], 0]$$

if $n < N - N_2$

$$x^{(n+1)}[N_2] = x[n + 1 + N_2]$$

if $n < N - N_2 - L_1$

$$\pi^{(n+1)}[N_2 + L_1] = \pi_{IN}^E[n + 1 + N_2 + L_1]$$

d. Estimate output variance $\sigma_b^2 = (\text{var}(\hat{b} | \hat{b} > 0) + \text{var}(\hat{b} | \hat{b} < 0))/2$

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e. Determine output priors, $\pi_{OUT}^E = 1/2 (1 + \tanh (\frac{\hat{b}[n]}{\sigma_{\hat{b}}^2}))$.

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